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COMMON TERNS NESTING ON NAVIGATIONAL AIDS AND NATURAL ISLANDS IN THE ST. LAWRENCE RIVER, NEW YORK

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ABSTRACT.—We evaluated breeding success of Common Terns (*Sterna hirundo*) on natural and man-made islands (navigational aids or cribs) in the upper St. Lawrence River, New York, to ascertain the importance of man-made habitats for conservation. Terns nesting on man-made sites had greater hatching and fledging success, 1.78 chicks per pair in 1984 and 2.00 chicks per pair in 1986, compared to those nesting at natural sites, 0.01 and 0.00 chicks per pair in 1984 and 1986, respectively. The difference in overall breeding success was attributed to higher avian predation at natural than at man-made sites. Natural sites appeared to be unsuitable habitat, whereas man-made islands appeared to be suitable. Between 1982 and 1990, the St. Lawrence River Common Tern population increased by 13%.
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The Common Tern (*Sterna hirundo*) breeds throughout the northern hemisphere of both the Old and New Worlds (Peters 1934, AOU 1983). In the upper St. Lawrence River (SLR), Common Terns were first observed in 1858 (Hadfield 1859). The first breeding record for upstate New York was noted in the SLR in 1917 (Merwin 1918). Subsequent reports suggest that there has been a continued occurrence of Common Terns in the upper SLR for more than 73 years (Courtney and Blokpoel 1983, Smith et al. 1984). Historical data for the period 1900–1982 indicate that the population was on the increase beginning in 1900, reached a peak of 1250 pairs in 1965 (Courtney and Blokpoel 1983, Smith et al. 1984), and then declined to an estimated 488 pairs by 1982 (Smith et al. 1984).

In other regions of the Great Lakes about 70% of terns nest at man-made sites. This shift from natural sites occurred as man-made sites became available through the 1970s and/or as natural sites were lost to a variety of abiotic and biotic factors (Courtney and Blokpoel 1983, Shugart and Scharf 1983). Our cursory observation in the SLR suggested a similar trend. Furthermore, it appeared that the present size of the population was now dependent on man-made navigation aids (cribs) that were constructed between 1973–1979. In this study, we document these observations.

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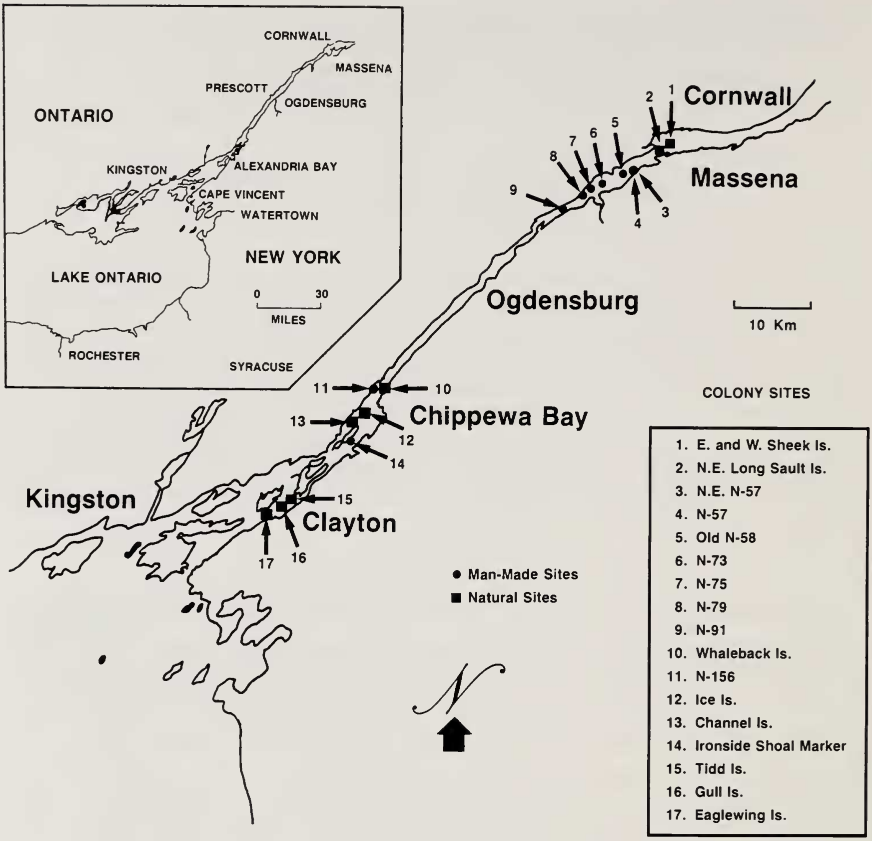

FIG. 1. Common Tern colony sites found along the upper St. Lawrence River, New York, in 1984.

STUDY AREA AND METHODS

We conducted this study in the 201-km long international sector of the St. Lawrence River between Clayton and Massena, New York (Fig. 1). Among the hundreds of islands and shoals in the study area, only 30 are historically known to have been used by nesting Common Terns (Courtney and Blokpoel 1983, Smith et al. 1984, Karwowski, pers. obs.). A total of nine natural islands were used in 1984, six of which were on the United States (U.S.) side of the river (Fig. 1). Of these sites, Eagle Wing Islands (EWI-1 and EWI-2) and Gull Island were selected for the study.

EWI-1 and EWI-2 are approximately 400-m^2, granitic-gneiss, rock outcroppings located 3300 and 2300 m, respectively, from the nearest mainland. Herbaceous vegetation typically grew in the very shallow, low lime, loamy soil that accumulated in the cracks and depressions of the rock (McDowell 1989). EWI-1 rises gently from water level on the east end to a maximum height of about 2.5 m on the steep west end. In contrast, EWI-2 rises gently from all sides to a maximum level above water of about 1 m. Both islands are prone to some over-spray and wash-over, i.e., flooding, from waves generated during strong winds.

Gull Island is a 800-m^2, granitic-gneiss rock outcropping located about 3 km east of the EWIs and 1700 m from the nearest mainland. The southern end of the island rises abruptly to about 6 m above water level and forms a flattened dome covering nearly 33% of the island. The remainder is relatively flat, rising about 1.5–2.0 m above water level and sloping gently toward the river. Thin (approx. 4 cm in depth) soil occurs in the central portion of the island, on the top of the "dome," and in cracks and depressions. It supports grasses, forbs, shrubs, and small trees. Gull Island is not exposed to wave-generated over-spray or wash-over.

Nineteen navigation aids are located in U.S. waters and are owned and maintained by the U.S. Dept. of Transportation, St. Lawrence Seaway Development Corporation, Massena, New York. All navigation aids are structurally similar and stand on the river bottom. Each marker consists of a cylindrical steel base, 8 m in diameter, that is partially filled with concrete, gravel, or soil, and a metal scaffolding that supports one or more types of navigation instruments. The surfaces are approximately level (forming a platform) with the upper rim of each base located about 2.5 m above mean water level. The height of the upper rim from the core substrate differs within and among the sites and ranges from 5–33 cm. Scaffolding is located at the center of each marker and ranges in height from 5–9 m.

In 1984 and 1986, eight markers were used by nesting terns (Fig. 1). Of these, we selected navigation light number 156 (N-156) and the Cat Island Shoal steering light (N-58) for intensive study. N-156 and N-58 had been filled with dredged river sediment that supported a moderately dense, herbaceous cover that uniformly covered the surfaces of both navigation aids. The surface area of both navigation aids was 50.3 m^2 and the distance from the substrate to the upper lip of the sheet piling ranged from 5–23 cm at N-156, and was 5 cm at N-58. N-156 and N-58 are located 3750 and 1050 m from the mainland, respectively.

In 1984, we studied breeding success and nest site habitat at EWI-1, EWI-2, Gull Island, and navigation aids N-156 and N-58. In 1986, we did a less intensive study of breeding success at EWI-1, EWI-2, Gull Island, and navigation aid N-156. We also collected data on the numbers of nesting terns and evidence of mortality at all active colonies during the period 1982–1990.

From mid-May to mid-July 1984 and 1986, we visited each colony daily by boat, except when prevented by rain. To minimize disturbance at the colonies, we limited our visits to ≤30 min and scheduled them during periods of moderate temperature and no precipitation. We marked all nests with a numbered stake and kept a detailed chronology on each nest and its contents until the last egg hatched or the nesting attempt failed, except in 1986, we marked a random sample of 22 nests at site N-156 for study. Egg fates were determined and reported using one of the following definitions: hatched—egg hatched; depredated—egg known to have been eaten or destroyed by predators or egg disappeared before it could have hatched; abandoned—egg left in nest no longer incubated by adults; died while pipping—egg began to hatch, but the chick did not emerge; flooded—egg in nest inundated with water or washed out of the nest by waves; failed to hatch—egg failed to hatch with others in the clutch or was incubated beyond 35 days; other—egg not retrieved from outside the nest, broken egg, or broken by investigators. Using 7 × 50 binoculars from a boat positioned 70–100 m offshore, we observed each colony site for night desertions on four separate dates. Dawn and dusk observations were made for one h beginning 30 min prior to sunrise and sunset, respectively, to determine night desertion and/or morning arrival behavior (Marshall 1942). We also measured incubation attentiveness for use as an indication of relative disturbance by determining the number of days clutches were incubated from their initiation to the hatching of the first egg, and compared mean incubation periods among sites.

Prior to eggs hatching, we erected a 30-cm-high, 2.5-cm hexagonal mesh wire fence around the perimeter of each navigation aid. The fence prevented chicks from prematurely jumping off the navigation aid into the river in response to our presence. As erected, they would have little effect in deterring avian predators. Once in the river, chicks would not have been able to return to the navigation aid. The natural islands gently sloped toward the edge of the river; consequently, fencing was unnecessary as chicks entering the water could easily return to the island. Chicks were banded within two days of hatching with a U.S. Fish and Wildlife Service leg band.

We determined chick survival on each visit by completely searching the colony and recording all chick encounters. This method was facilitated by the small size and relatively sparse vegetation on the sites. Chicks that were not found on a given visit were usually found (>96%) during the next visit. Unless missing chicks were found during later visits, they were assumed to have been depredated. We considered chicks alive more than 18 days to have fledged, because after that time chicks could escape the enclosure on the navigation aids (Smith et al. 1984). We collected information on the fate of each chick until it died, disappeared, or was considered to have fledged (>18 days old).

We defined (a) hatching success for nests as the number of eggs hatched per eggs laid, (b) fledging success for nests as the number of chicks fledged per eggs hatched, and (c) breeding success for colonies as the number of young fledged per breeding pair, i.e., nest, for each colony. To evaluate hatching success and fledging success with respect to nest-site characteristics, we recorded in 1984 at the time the first egg hatched vegetation cover (%) and height (cm) within a 50-cm-radius, circular plot centered over the nest (Blokpoel et al. 1978); substrate beneath nest (soil, grass, gravel, or bedrock); number of neighboring nests within a 1-m radius of the nest; and distance (m) to nearest neighboring nest.

To evaluate the association of the observed shift in nesting habitat with the status of the Common Tern population, we compiled all available tern nesting data for the area from 1982–1990. The primary sources of data were observations by KK (1982–1990), LHH (1990 unpubl. data), and G. A. Smith (1982–1989 unpubl. data). In both 1984 and 1986, five visits were made by boat to every active Common Tern colony within the SLR at two-week intervals beginning around 22 May in each year. On each visit, an effort was made to count all nests in every colony. Colony size was determined by counting the number of nests at peak incubation to avoid counting renesting terns. Presence or absence of predation and relative hatching and fledging success were noted at all active sites. To determine if new colony sites had gone undetected, two complete searches of the river for new colonies were conducted in 1984 and 1988.

Nonparametric statistical procedures were used in data analyses because the assumptions of normality and homogeneity of variance could not be met. Chi-square (χ^2) tests for two independent samples, Wilcoxon-Mann-Whitney test, and Kruskal-Wallis one-way analysis of variance were used to compare clutch sizes, incubation attentiveness, hatching and fledging success, and egg fates within and among colonies. When the values of the Kruskal-Wallis test were significant ($P < 0.05$), we tested the significance of difference between colony sites using the multiple comparisons test described by Siegel and Castellan (1988). To examine the relationships among the nest-site variables measured in relation to hatching and fledging success, we used hierarchical log-linear analysis (HILOGLINEAR, SPSS/PC, V3.1) using backward elimination to test for significant interactions (Norusis 1985).

RESULTS

Breeding success and nest site characteristics.—The modal clutch size for all sites in 1984 and 1986 was three eggs, but larger clutches (four

TABLE 1

CLUTCH SIZE DISTRIBUTION, CLUTCH SIZE, AND LENGTH OF INCUBATION (MEAN ± SE) AMONG COMMON TERN COLONIES IN THE UPPER ST. LAWRENCE RIVER, NEW YORK, 1984 AND 1986[a]

Year	Colony	Clutch size distribution 4	3	2	1	Clutch size	Incubation (days)
1984	EWIs	0	34	6	5	2.64 ± 0.10 (45)A	30.3 ± 1.65 (6)A
1984	Gull Island	0	43	6	5	2.70 ± 0.09 (54)A	31.2 ± 0.49 (5)A
1984	N-156	0	59	0	5	2.84 ± 0.07 (64)A	23.5 ± 0.61 (13)B
1984	N-58	2	108	9	2	2.91 ± 0.04 (121)A	22.9 ± 0.31 (14)B
1986	EWIs	1	44	12	7	2.61 ± 0.09 (64)A	29.7 ± 1.86 (3)A
1986	Gull Island	0	22	2	9	2.39 ± 0.16 (33)A	31.2 ± 0.39 (13)A
1986	N-156	16	32	4	2	3.15 ± 0.10 (54)A	22.4 ± 0.26 (8)B

[a] Significant differences between colonies in each year are shown by differences in letters within each column (nonparametric multiple comparison method, $P < 0.05$). Sample sizes are in parentheses.

eggs) were found in both years. Clutch sizes did not differ among the sites in either year (Table 1), but incubation attentiveness by adult terns did. In both years, incubation length was longer at colonies on natural sites than on man-made sites (Table 1).

In 1984, hatching success and the number of eggs hatched per nest at the man-made sites (for all nests with different clutch sizes pooled) differed significantly from that at the EWIs, but not from that at Gull Island (Table 2). In 1986, hatching success and the number of eggs hatched per nest at N-156 were significantly higher than at either natural site. Both hatching success and the number of eggs hatched per nest also differed between Gull Island and the EWIs, being higher at Gull Island (Table 2).

Large clutches (3–4 eggs) had significantly higher hatching success than small clutches (1–2 eggs) at both natural sites and at N-156 during 1984 (Table 3). In 1986, large clutches had higher hatching success at Gull Island, whereas all clutch sizes experienced low hatching success at the EWIs. No clutch size comparisons were made at N-156 during 1986, because all clutches in our random sample contained three eggs (Table 3).

A comparison of the number of eggs hatched by habitat type in 1984 and 1986 showed that nests on the man-made sites had more eggs hatch than expected, whereas nests on natural sites had fewer eggs hatch than expected (Chi-square test for two independent samples; $\chi^2 = 129.24$, df $= 6$, $P < 0.001$ and $\chi^2 = 117.57$, df $= 5$, $P < 0.0001$, respectively). Partitioning of the Chi-squares showed that in 1984, the frequencies of egg predation, abandonment, flooding, and chicks that died while pipping were higher for nests on natural sites and lower for nests on man-made

TABLE 2

MEASURES OF BREEDING SUCCESS (MEAN ± SE) AMONG COMMON TERN COLONIES IN THE UPPER ST. LAWRENCE RIVER, NEW YORK, 1984 AND 1986[a]

Year	Colony site	Hatching success	No. eggs hatched per nest	Fledging success[b]	No. chicks fledged per nest with hatched eggs	No. chicks fledged
1984	EWIs	0.41 ± 0.07 (43)A	1.19 ± 0.20 (43)A	0.00 ± 0.00 (21)A	0.00 ± 0.00 (21)A	0
1984	Gull Island	0.76 ± 0.05 (51)B	2.16 ± 0.16 (51)B	0.02 ± 0.02 (41)A	0.04 ± 0.04 (41)A	2
1984	N-156	0.91 ± 0.03 (57)B	2.72 ± 0.10 (57)B	0.68 ± 0.04 (43)B	1.87 ± 0.14 (43)B	84
1984	N-58	0.93 ± 0.02 (109)B	2.75 ± 0.05 (109)B	0.61 ± 0.03 (82)B	1.69 ± 0.10 (82)B	142
1986	EWIs	0.09 ± 0.03 (64)A	0.23 ± 0.09 (64)A	0.00 ± 0.00 (7)A	0.00 ± 0.00 (7)A	0
1986	Gull Island	0.46 ± 0.09 (33)B	1.33 ± 0.25 (33)B	0.09 ± 0.09 (11)A	0.11 ± 0.17 (11)A	3
1986	N-156	0.92 ± 0.04 (22)C	2.77 ± 0.11 (22)C	0.74 ± 0.06 (22)B	2.00 ± 0.17 (22)B	44

[a] Significant differences between colonies in each year are shown by differences in letters within each column (nonparametric multiple comparison method, $P < 0.05$). Sample sizes are in parentheses.

[b] Chicks survived >18 days.

TABLE 3

HATCHING AND FLEDGING SUCCESS (MEAN ± SE) OF 1–2 AND 3–4 EGG CLUTCHES AT COLONY SITES IN THE UPPER ST. LAWRENCE RIVER, NEW YORK, 1984 AND 1986[a]

Year	Colony	Clutch size	Hatching success	Fledging success[b]
1984	EWIs	1–2	0.18 ± 0.08 (11)	0.00 ± 0.00 (4)
		3–4	0.49 ± 0.08 (32)*	0.00 ± 0.00 (17)NS
1984	Gull Island	1–2	0.45 ± 0.14 (10)	0.00 ± 0.00 (6)
		3–4	0.82 ± 0.05 (41)**	0.02 ± 0.02 (35)NS
1984	N-156	1–2	0.00 ± 0.00 (3)	— (0)
		3–4	0.96 ± 0.02 (54)**	0.68 ± 0.04 (43)[b]
1984	N-58	1–2	0.72 ± 0.15 (9)	0.33 ± 0.33 (3)
		3–4	0.96 ± 0.01 (100)NS	0.62 ± 0.03 (79)NS
1986	EWIs	1–2	0.10 ± 0.07 (19)	0.00 ± 0.00 (2)
		3–4	0.08 ± 0.04 (45)NS	0.00 ± 0.00 (5)NS
1986	Gull Island	1–2	0.09 ± 0.03 (11)	0.00 ± 0.00 (1)
		3–4	0.64 ± 0.14 (22)**	0.10 ± 0.10 (10)NS
1986	N-156	1–2	— (0)	— (0)
		3–4	0.92 ± 0.04 (22)[c]	0.37 ± 0.06 (22)[c]

[a] The Wilcoxon-Mann-Whitney test for two independent samples was used to test for differences. Sample sizes are in parentheses.
[b] Chicks survived >18 days.
[c] Comparison was not made since all nests in the random sample contained three eggs.
* $P < 0.05$, ** $P < 0.01$, NS—not significant.

sites ($\chi^2 = 47.66$, $P < 0.0005$; $\chi^2 = 21.69$, $P < 0.001$; $\chi^2 = 52.51$, $P < 0.0005$; and $\chi^2 = 5.77$, $P < 0.02$; respectively). In 1986, the frequency of egg predation, nest abandonment, and flooding were higher than expected for nests on natural sites and lower than expected on man-made sites ($\chi^2 = 97.40$, $P < 0.0005$; $\chi^2 = 7.66$, $P < 0.01$; and $\chi^2 = 7.49$, $P < 0.01$; respectively).

The significantly greater hatching success at the man-made sites in 1984 was not explained by the data for the measured nest site characteristics. The relationships among the habitat measurements and hatching success were not statistically significant (HILOGLINEAR, $\chi^2 = 171.153$, df = 172, $P > 0.05$, all $z < 1.96$, $P > 0.05$).

Colonies at man-made sites produced significantly more young per nest than did the colonies at natural sites (Table 2). We found no difference in fledging success between small (1–2 eggs) and large (3–4 eggs) clutches (Table 3). Overall, the terns at natural sites experienced near total reproductive failure in both years, and the terns at the EWIs colony did not fledge young in either year (Table 4). In 1984, 68% of all chicks produced at the Gull Island colony were taken by predators, and 30% died in or at their nests. At the EWIs colony, 88% of the chicks produced

TABLE 4

SUMMARY OF CHICK FATES FOR COMMON TERN COLONIES STUDIED IN THE UPPER ST. LAWRENCE RIVER, NEW YORK[a]

	1984				1986		
Chick fates	Eagle Wing islands	Gull island	N-156	N-58	Eagle Wing islands	Gull island	N-156
Chicks hatched	51	110	155	300	15	44	61
Confirmed fledged	0	2	84	142	0	3	44
Presumed depredated	45	60	0	0	15	35	0
Died on site	6	33	14	28	0	6	0
Presumed fledged	0	2	141	172	0	3	61
Chicks fledged per nest with hatched eggs[b]	0.00 ± 0.00 (21)	0.04 ± 0.04 (41)	1.87 ± 0.14 (43)	1.69 ± 0.10 (82)	0.00 ± 0.00 (7)	0.11 ± 0.11 (11)	2.00 ± 0.17 (22)
Chicks fledged per nest with eggs[b]	0.00 ± 0.00 (43)	0.04 ± 0.04 (51)	2.20 ± 0.16 (57)	1.42 ± 0.09 (109)	0.00 ± 0.00 (64)	0.09 ± 0.08 (33)	[c]
Age at disappearance in days	4.5 ± 0.52 (45)	2.2 ± 0.29 (60)	—	—	3.9 ± 1.08 (15)	3.9 ± 0.40 (41)	—
Age at death (days)	2.5 ± 0.22 (6)	3.4 ± 0.59 (33)	8.6 ± 1.36 (14)	3.5 ± 0.46 (16)	—	2.3 ± 0.33 (3)	—

[a] Means (±SE) are presented where appropriate. Sample sizes are in parentheses.
[b] Fledged means chick survived >18 days.
[c] Could not be determined from the subsample data.

were taken by predators and the remainder (12%) died in their nests. The fate of chicks at both natural sites was similar in 1986. Eighty-five percent of the chicks produced at Gull Island and 100% of the chicks at the EWIs colony were depredated. In addition, 15% of the chicks at Gull Island were found dead near their nests.

Based on direct observation and circumstantial evidence at the natural sites, we believe that Great Horned Owls (*Bubo virginianus*) in the SLR caused the direct loss of Common Tern adults and pre-fledgling chicks and the indirect loss of pipping eggs and newly hatched young to exposure resulting from nocturnal nest desertion by adults. No signs of predation or nocturnal nest desertions were observed at the man-made sites. Our observations of night desertion and morning arrival behavior indicated that adult terns often deserted the natural islands for 6.5–8 h. We also observed a Great Horned Owl on the EWIs just after sunrise and, consistent with owl predation, found owl feathers, decapitated chicks, and wings, bills, and feathers of adult terns at every visited natural site.

HILOGLINEAR analysis of fledging success in relation to the habitat variables measured in 1984 produced a final model which contained statistically significant second-order interactions between fledging success and nest density. Nests which failed to fledge any young were associated more frequently than expected with nest densities in the categories low (1–4 nests) density ($\lambda = -0.0726$, $z > 3$, $P < 0.01$) and medium (5–8 nests) density ($\lambda = -0.3924$, $z > 2$, $P < 0.05$), than those in the category high density (>8 nests).

Shifts in nesting habitat use and population trends.—In 1976, Common Terns were observed for the first time nesting on a navigation aid (van Riet, pers. comm.). From 1977 to 1980, at least two navigation aids were used by nesting terns. By 1982, eight navigation aids were being used for nesting (Smith, unpubl. data; Karwowski, pers. obs.) (Fig. 2). Sites N-57, N-58, N-73, N-75, and N-79 were colonized within 1–3 years after their installation. Site N-156 was first known to be used within six years of its construction, N-180 was colonized within 15 years, and N-91 was colonized 18 years after being placed in the river.

Prior to 1982, nine natural sites which were known to have been used by nesting Common Terns (Bull 1974, Blokpoel 1977, Karwowski and Smith, unpubl. data) became unusable. Five sites (Black Ant, Scorpion, West Bergen, Bogardus, and Murray islands) were taken over by earlier nesting Ring-billed Gulls (*Larus delawarensis*). Two sites (Big and Little Murphy islands) became overgrown with vegetation. Between 1982 and 1990, five additional sites were eliminated from the pool of available tern nesting sites. Ice Island, historically the largest natural colony site, was taken over by Ring-billed Gulls; West Sheek Island was destroyed by flooding and erosion; Old Man Island was overgrown with vegetation; and East Sheek Island, Stovin Island, and Sheaffle Island shoal were not used for unknown reason(s). The number of colonies on natural islands declined from a high of 11 in 1982 to a low of six in 1990 (Fig. 2).

In 1982, over 37% (181 out of 488 nests) of the tern breeding population nested on navigation aids (Fig. 2). By 1990, the use of navigation aids by nesting terns had increased to nearly 70% (384 out of 557 nests), with most concentrated at N-58, N-73, N-75, N-79, and N-156. Between 1982 and 1990, the number of nesting terns increased an average two percent annually, resulting in an overall increase of about 13% for the period. During this period, the population size averaged 546 ($\pm$12 SE) breeding pairs and ranged from a low of 488 in 1982 to a high of 596 in 1989 (Fig. 2). Although there has not been a major increase in the total number of nests of Common Terns from 1982 to 1990, there has been a decline in numbers of nests on natural islands with a corresponding increase in numbers on navigation aids. As the number of nests per colony on natural islands has not changed appreciably, the decline on natural islands has been due primarily to site abandonment. In comparison, the increase in nests on navigation aids has been due mainly to higher densities of nests rather than to an increase in number of navigation aids used by terns.

DISCUSSION

Both direct and indirect effects of predation were discernible at the natural sites, but not at the man-made sites, and accounted for the substantially higher breeding success of terns nesting at the man-made sites. The consequences of avian predation at Common Tern colonies are well documented (e.g., Nisbet 1975, Hunter and Morris 1976, Nisbet and Welton 1984, Morris and Wiggins 1986). The principal avian predator of adult Common Terns in North America is the Great Horned Owl. Predators of tern eggs and/or young include Black-crowned Night-Herons (*Nycticorax nycticorax*), Ruddy Turnstones (*Arenaria interpres*), Herring Gulls (*Larus argentatus*), and Canada Geese (*Branta canadensis*) (Courtney and Blokpoel 1980, Morris and Wiggins 1986, Burger and Gochfeld 1991). Ruddy Turnstones were observed puncturing and eating tern eggs (typically between 20–29 May), but their overall contribution to egg losses was not

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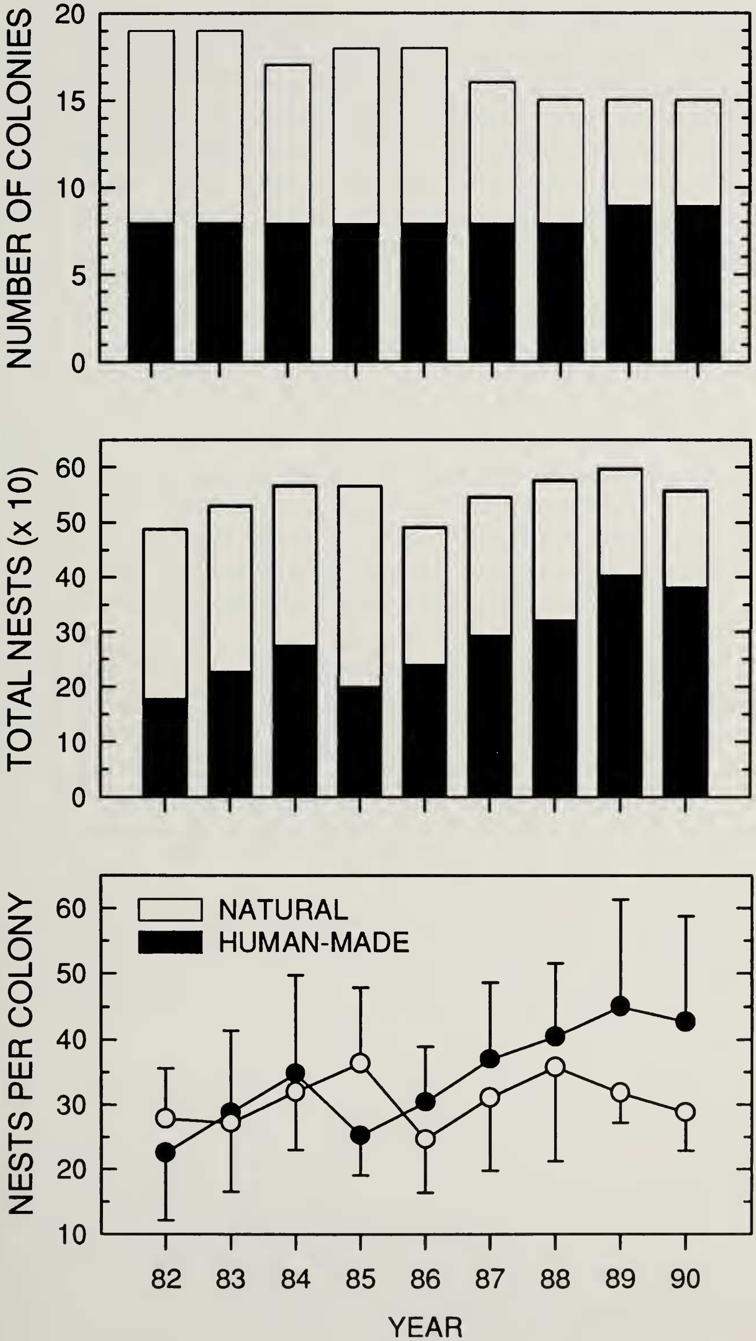
FIG. 2. Number of colonies, total nests, and mean ($\pm$SE) number of nests per colony on man-made and natural sites from 1982–1990 in the upper St. Lawrence River, New York.


NUMBER OF COLONIES
20
15
10
5
0
TOTAL NESTS (x 10)
60
50
40
30
20
10
0
NESTS PER COLONY
60
50
40
30
20
10
NATURAL
HUMAN-MADE
82
83
84
85
86
87
88
89
90
YEAR

quantified. In addition, two suspected predators of eggs and chicks were Great Blue Herons (*Ardea herodias*) and Black-crowned Night-Herons. Although we have no direct evidence, their contributions to egg and chick losses may have been substantial. Indirect losses were a consequence of nocturnal desertion of the sites by the adults, which was observed following the depredation of adult terns. The significantly longer incubation lengths and numbers of eggs which died pipping or that were abandoned are clear indicators of parental neglect.

Common Terns nesting in the SLR at natural sites undoubtedly have had a long history of exposure to Great Horned Owl predation (Waltz, pers. comm.). Because owls are highly territorial and nest-site tenacious (Craighead and Craighead 1969), high predation pressure at a tern colony in one year likely would be a good predictor of high predation pressure in subsequent years. Terns at colonies faced with avian predation certainly would have the opportunity to avoid predation in subsequent nesting attempts or years by using alternate colony sites. Owls would then stop visiting the former site because there would be no prey. It is likely that terns would continue to nest at the alternate site until predators discovered them. A colony would then move to another site that would be usable for a few years until discovered again.

Between 1982 and 1990, the natural and man-made sites used by nesting Common Terns were subjected to differing environmental conditions, which may have ultimately affected their suitability as tern nesting habitats. At the natural sites, terns were faced with high rates of predation, nest-site competition, risk of nest flooding, vegetation succession, and/or human disturbance (Smith et al. 1984; Karwowski, pers. obs.). Terns faced with high predation pressure had fewer choices of suitable, alternate nest sites. Some terns may have remained at sites which had high predation pressures due to colony- and nest-site fidelity (see Patton and Southern 1978, Southern and Southern 1979), whereas some individuals may have attempted to nest at novel sites to avoid predation, despite the potential for reducing their breeding success (McNicholl 1975, Erwin et al. 1981).

Terns nesting on navigation aids must have found nesting conditions to be quite different from those on natural islands. Unlike at natural sites, at man-made sites we found no evidence of depredation of eggs, chicks, or adults (e.g., perforated eggs, shell fragments, lengthened incubation periods, night desertion, or parts of chicks or adults). Distances of navigation aids and natural islands from the mainland were not significantly different (Karwowski and Gates, unpubl. data), so owls should have had no problem in reaching navigation aids. Perhaps owls were deterred by the scaffolding of the navigation aids. Interspecific competition for nest sites also did not occur. Ring-billed Gulls have never been observed nesting on navigation aids, possibly because they have experienced no selective pressures to use them. Nests were not exposed to flooding because the nesting substrates were about 3 m above water level and well drained. All sites supported early successional vegetation preferred by nesting terns (Blokpoel et al. 1978). Furthermore, human disturbance such as recreational fishing or sight-seeing was rarely observed. Because of the high fledging success, these initial colonists and their offspring would likely have chosen to nest on navigation aids in the future.

Assuming that the upper SLR population is discrete with little or no movement to or from other areas, as reported for the Great Lakes population (Courtney and Blokpoel 1983), and that the rate of mortality outside the study area is comparable to other areas such as Massachusetts (Nisbet 1978) and Great Gull Island, New York (DiCostanzo 1980), a reasonable prediction about the long-term effects of the shift in habitat use by nesting terns on the size of their future breeding population can be made. The greater breeding success of Common Terns nesting at man-made sites and the increasing number of terns using those sites annually strongly suggest continued breeding population stability or increases on the SLR. Without active management of natural islands (Morris et al. 1992), tern colonies on the man-made sites likely will continue to be source populations for what would otherwise be a declining regional population. Because tern populations are so dependent upon these man-made sites for successful nesting, annual monitoring should be done to confirm their continued success and to address any potential problems that might arise.

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